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A MODERNIZATION PLAN FOR THE TECHNICAL DATA DEPARTMENT OF THE NAVAL SHIPS WEAPON SYSTEMS ENGINEERING STATION

by

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17 May 1977

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The work reported herein was supported in part by the Naval Ships Weapon Systems Engineering Station under Contract # 56963.

This report was prepared by:

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER NPS-53Wg77052	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A MODERNIZATION PLAN FOR THE TECHNICAL DATA DEPARTMENT OF THE NAVAL SHIPS WEAPON SYSTEMS ENGINEERING STATION		5. TYPE OF REPORT & PERIOD COVERED Technical Report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Assoc. Prof. Peter C. C. Wang		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS N6339477WR0703T
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Ships Weapon Systems Engineering Station Port Hueneme, California 93043		12. REPORT DATE 17 May 77 13. NUMBER OF PAGES 33
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Technical Data
Modernization Plan
Acquisition

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A methodology is presented which utilizes an intraorganizational structure to coordinate a modernization that requires the acquisition of facilities involving high technology. This methodology is then applied to a proposed modernization of the Technical Data Department of the Naval Ships Weapon Systems Engineering Station, Port Hueneme, California. The results of this application are initial recommendations for an acquisition coordinating structure to reduce technical and organizational risks.

A MODERNIZATION PLAN FOR THE TECHNICAL DATA DEPARTMENT OF THE NAVAL SHIPS WEAPON SYSTEMS ENGINEERING STATION*

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Abstract

A methodology is presented which utilizes an intraorganizational structure to coordinate a modernization that requires the acquisition of facilities involving high technology. This methodology is then applied to a proposed modernization of the Technical Data Department of the Naval Ships Weapon Systems Engineering Station, Port Hueneme, California. The results of this application are initial recommendations for an acquisition coordinating structure to reduce technical and organizational risks.

1. INTRODUCTION

One of the missions of the Naval Ships Weapon Systems Engineering Stations (NSWSES - commonly called "Nemesis") is maintaining the engineering drawings and documentation (both current and archival) for shipboard weapon systems, and providing copies, as required, to users.

At present, this data base at NSWSES consists of approximately 3 million sequenced 35mm aperture microfilm cards. When a request is received for drawings, a computer generates a "slave deck" of IBM cards, which contains the card sequence identifiers of the aperture cards which hold the required drawings. This slave deck is then run against the data base in a mechanical collator, and the correct aperture cards pulled. After the microfilms have been copied, the aperture cards are remerged into the data base. The drawbacks of this are many, the most obvious being:

(1) Damage to the aperture cards due to mechanical and human handling,

(2) Loss of portions of the data base while microfilm copies are being made,

(3) Loss of portions of the data base due to out-of-sequence cards, and

(4) Slow response due to lack of random access.

NSWSES is considering replacing this system with an automated one, where the engineering drawings are digitally stored in a random access file. The overall objective of this paper is to establish a foundation which can be utilized by NSWSES in the development of a modernization plan for the station's data management system. The intent is to provide an understanding of the scope of the considerations which impact this development, and to present a framework which will insure that these considerations are included in the specification

*This is partially supported by NSWSES under contract 56953 with the Mathematics Department at the Naval Postgraduate School.

**This article is written based on material included in a master's thesis by LT John W. Pounds, USN and LCDR Billie W. Wieland, USN.

of system requirements.

1.1 METHODOLOGY

The methodology presented here was devised to provide an intraorganizational structure to coordinate a modernization that will include the acquisition of facilities involving high technology. Our output of this is to identify critical issues and key organizational structures which should be formed to coordinate the process. A block diagram of the methodology is shown in Fig. 1, and a brief description of each block is contained below. We emphasize that the steps shown in the methodology are not necessarily serial, but work on several portions may proceed simultaneously. The first consideration is to define clearly the character of the present organization. The key questions on this are shown in Table 1. With a clear understanding of the organization's present mission and how it fulfills its responsibilities, we can identify the problems that presently exist. These problems may be related to internal structure, process, procedures or a combination of these, or their key elements may lie in external factors such as additional responsibilities, or unforeseen growth. In each case, the causes must be identified. (This is not to suggest that a simple single cause/ single problem relationship will always exists. "Group" of causes that manifest themselves in a "group" of problems may need to be identified.) This forms the basis of projection of how the nature of the identified problems might change in the future.

To assess the degree of modernization needed, the "causes" identified in the preceding paragraph must be projected into the future. Since the term "cause" has a static connotation, we will use instead the term "variable", to mean a cause that changes over time.

The techniques for projecting these will vary from "best estimates" by key experts, to sophisticated statistical procedures, depending upon the amount and nature of the data available, whether the variables are quantifiable, etc.

Since not all the variables need increase in impact, but may decrease, even to insignificance, and also, since significant unforeseen variables may appear during the process, the methodology we propose is a dynamic process. There is no separation between planning and implementation since this might lead to a solution to problems that no longer exist and to problems that the solution does not address.

TABLE 1

Key Questions on Present Organizational Character

a. Organizational History
   - (1) How did the organization and its mission evolve?
   - (2) What external factors influenced this evolution?
   - (3) Was the growth pattern evolutionary or revolutionary?

b. Organizational Structure
   - (1) What is the structure? functional? vertical? etc.?
   - (2) What are the formal/informal lines of communication?

c. Organizational Process
   - (1) What are the inputs to each component?
   - (2) How does each component utilize its resources to process these inputs?
   - (3) What are the outputs?
   - (4) Who are the users of these outputs?

d. Organizational Procedures
   - (1) What are the specific procedures that each component uses in fulfilling its function?
   - (2) How do these procedures mesh with those of other components?

The system definition is the first step toward identifying specific hardware characteristics required. It is the buffer between identifying general functional need and the definition of specific technical parameters of the actual hardware. (The general functional needs of the organization should be derivable after the analysis has identified the future impact of the variables). It should include an initial identification of possible technical alternatives, and definition of key areas for technological review.

The initial review of technology is not an assessment of specific hardwares of specific manufacturers, but a general investigation of the industries which appear to be developing products that will satisfy the need. The technological review should be able to impact the system definition by indicating the risk associated with proposed alternatives.

The review of presently operating systems should concentrate on systems similar to the one conceived in the definition phase. This review can provide critical information on possible pitfalls, and may also provide an insight to possible changes in organizational structure required by a more modern technical approach.

Again, it should be emphasized that this process of establishing a system definition, through technical and operational system reviews is dynamic and iterative. It must be a continuous process to ensure that the hardware characteristics contracted for will (1) support a system that is consistent with the projected nature of the variables, (2) utilize a technology that will be neither obsolete nor unattainable and (3) reflect the lessons of other systems to avoid replication of errors and to embrace sound technical and organizational procedures.

To avoid confusion, we draw a distinction between the terms "acquisition" and "procurement." For the purposes of this paper, the process of acquisition involves planning, coordination, tradeoff analysis, cost estimating, procurement planning, procurement, and assessment of the procurement activity. Procurement is a subset of acquisition and involves contract definition, installation, checkout, and phased-in operation.

Acquisition planning could involve a steering committee structure or it might be limited to a few upper/middle level management personnel who will decide on a procurement plan.

If the system is a single purchase, this plan would give the specific hardware characteristics that are required in the contract definition. If the purchase involves separate phases, the plan must contain specific hardware characteristics for Phase 1 and intergration and timing plans.

This methodology will now be used to address the NSWSES modernization.

1.2 HISTORICAL BACKGROUND

During the latter part of World War II and in subsequent years the Navy has continued a concentrated effort toward the development and installation of highly complex weapon systems aboard Navy surface ships. The need for a field activity which could provide a concentrated source of support requirements for Surface Missile Systems (SMS) led to the establishment of the Naval Ship Weapon Systems Engineering Station (NSWSES) at Port Hueneme in 1963.

The station's primary task was to upgrade the reliability and performance of the Terrier, Tartar, and Talos missile systems which were then deployed in the fleet. As a foundation for providing total system support, a configuration baseline was established from data collected through direct contact with the fleet and from system contractors. The station's Technical Data Department provides the centralized location for the storage, updating and retrieval of this technical data.

The responsibilities of NSWSES have grown over the years and it is now involved in the support of many systems in addition to surface missile systems. These systems include some Gun Fire Control Systems, Surface Weapons Switchboards, Search Radars, the AEGIS program, the Anti-Ship Missile Defense System, the Point Defense System, the Standard Missile, Nato Sea Sparrow and the Harpoon Missile as well as the continued support of the original Terrier, Tartar and Talos Missile Systems. To meet the future requirements for accurate and timely technical data support the responsible department must seek new and improved techniques to update, store and retrieve technical data.

The data management system currently in use in the Technical Data Department is based on the data management and storage technology which existed in the early to middle sixties when the station was founded. NSWSES personnel have indicated that the data files which have been developed are not well integrated, leading to redundant storage of data and inefficient methods for manipulating data often involving several manual steps which could be automatically performed with modern data management techniques.

2. CONFIGURATION MANAGEMENT - THE PRESENT SYSTEM

2.1 SYSTEMS SUPPORTED

The type of systems supported by NSWSES was briefly discussed in Section 1. The amount of support for these systems may be as little as a specific task to correct a given problem or as much as total engineering support including logistics and data management. In the past, this has been an evolutionary growth beginning with a technical involvement and proceeding to logistics and data management as the station gained in engineering expertise.

As the concept of the totally integrated weapon system grows, more emphasis is being placed on equipments that interface with the major missile systems, such as, search radars and guns. Fig. 2 shows the present systems which are completely supported by the Technical Data Department.

2.2 TECHNICAL DATA DEPARTMENT

The two divisions comprising the Technical Data Department (Code 5100) are the primary source of configuration and data management for NSWSES systems (see Fig. 3). The department is tasked with coordination and control of data requirements for NSWSES supported equipments throughout their life cycle. In fulfilling this requirement, the department becomes involved with data acquisition at a detailed level including: identification of need, procurement coordination, validation, standardization, quality assurance, review and revision of existing policies and standards, and cost analysis. Furthermore, the department must develop and maintain an Integrated Configuration Management Data System (ICMDS) to provide baseline identification, configuration status, and associated engineering planning for designated ships, sites, systems, equipments and configuration items.

The Data Management Division (Code 5120) specifies and standardizes the content, form, and production of technical data. It monitors, reviews, and provides services for preparation, acquisition, and release of technical data. Furthermore, the division authenticates and releases complete design disclosure information subsequent to approval of the documentation by the appropriate engineering department. The division is comprised of three branches: Data Requirements Branch (Code 5121), Data Standardization Branch (Code 5122), and Design Disclosure and Review Branch (Code 5123). Each of these branches acts as an initial input and a prospective user of ICMDS. Specific functions of these branches can be found in reference 1.

The Configuration Division (Code 5130) acts as the NSWSES point of contact for configuration matters, performs configuration planning, identification, status accounting, change control coordination, and configuration audits. The division is comprised of three branches: Identification and Provisioning Branch (Code 5131), Status Accounting and Change Secretariat Branch (Code 5132), Data Information Branch (Code 5133). Each of these branches is responsible for maintaining a file which directly supports ICMDS. These branches use a variety of files to support their functions.

The identification and Provisioning Branch maintains the Configuration Item Identification File (CIIF), which provides storage and retrieval capability for technical and logistics data specified on an engineering drawing. The Status Accounting and Change Secretariat Branch maintains two Configuration Status Accounting (CSA) files. The Site File contains descriptive information of all NSWSES cognizant equipment as well as site location data. Information includes sub-system usage, EIC, nomenclature, designation and serial number. The Class 1 Change File contains information on applicable equipment changes including purpose, logistic data, where applicable and authority. The Data Information Branch maintains the Automated Aperture Card File (AACF). This contains computer cards with affixed microfilm of engineering drawings of NSWSES supported equipments. Specific functions of these branches can be found in reference 1.

2.3 FILE CHARACTERISTICS

The interaction of the Configuration Division and other agencies is predicated on the division's capability to transmit timely information in useful form to the prospective user from one of the four files discussed below. A detailed description of the inputs, outputs and users for each of these files can be found in reference 1.

The Site and Class 1 Change Files are stored on two reels of magnetic tape. The Site File covers approximately 575 sites and 1600 equipments. The Class 1 Change File contains approximately 4500 changes affecting equipment configuration. These changes may be in the form of Engineering Change Proposals (ECP) or Ordnance Alterations (ORDALT). An ORDALT is a change which has been reviewed as an ECP and authorized for accomplishment on Fleet equipments. Approximately 1200 ECP's and 167 final ORDALT texts are processed through these files yearly.

The Configuration Item Identification File (CIIF) is stored on 17 reels of magnetic tape. The file covers all major SMS and some Gun Fire Control Systems (GFCS) equipment (less expendables and missiles). It also covers all SMS test equipment, 6 guided missile checkout equipments and 193 ancillary equipments. These system responsibilities result in approximately 3 million line items and is/was data on over 550 active ORDALT's. Approximately 10 major equipment provisionings, 5 minor equipment provisionings, 60 ORDALT's and 5 APL reviews are processed through this file yearly.

The AACF consists of approximately three million master aperture cards and the corresponding computerized Master Inventory File (MIF). The inputs to both files are manufacturer drawings for supplied equipments and revised drawings from contractor or engineering codes. The aperture card file acts as a repository for engineering drawings to ships, shipyards, repair facilities and engineering codes.

2.3.1 File Maintenance Procedures.

Both the CSA files and the CIIF are maintained with the use of loading forms. Each file has a number of different types of forms depending upon the nature of the transaction. Once the transaction has been coded, the forms are keypunched onto a magnetic tape and sent to the computer facility for processing.

At present, NSWSES has no dedicated computing facility. It utilizes the Naval Facilities Engineering Command (FACSO) facility which is located approximately two miles away. This results in a substantial time lag between runs during the update process because 1) the computing facility is not primarily used for configuration management and therefore processing must be scheduled; 2) errors in loading forms or subsequent keypunching are not caught until computer processing is completed and returned to the originator.

NSWSES personnel indicate that the average time required to perform a parts listing for an average equipment is five weeks. During this time, the data is not available to any user.

Maintenance of AACF requires more physical processing. When an engineering drawing is received, it is initially checked for resolution, density, proper format, and other MIL-standard specifications. The drawing is then filmed with a KODAK MRG 35 MM or 3M 2000E camera to obtain a microfilm. The microfilm is used to keypunch a slave deck. The microfilm is attached to an aperture card and these cards are run through an IBM reproducer with the slave deck to transfer the information from the slave deck to aperture cards. The slave deck is forwarded to the data processing center to update the master inventory file. After the aperture cards are interpreted to convert the keypunched information to print, they are placed into the AACF by using IBM collators. The collator automatically files the cards into the proper sequence and eliminates the need for human filing, thus reducing filing errors. The original drawings are sent to a local repository.

2.4 THE NEED FOR CONFIGURATION MANAGEMENT - AN EXAMPLE

The MK - 10 Guided Missile Launching System provides the launcher capability for the Terrier Guided Missile System. It is also used as a launching system for ASROC and HARPOON. The system has a history of reliable performance, ease of maintenance, and flexibility in responding to varying requirements. There are presently nine Mods to the launching system. Different Mods are used on missile capable aircraft carriers, double-ended and single-ended CG's, and DDG's.

From 1957 to 1975, the system had 60 Ordnance Alterations (ORDALT's). These ORDALT's were not applicable to all Mods but did affect an average of 40 ships per alteration. At present, 20 of these ORDALT's are outstanding in that they have not been completed on all ships to which they are applicable. The oldest of these outstanding ORDALT's was authorized in May 1969. This means that over the last seven years, numerous configuration differences have existed in the launcher system in the Fleet. Even if each ORDALT was installed on all applicable ships simultaneously, thousands of possible combinations would exist.

There are many reasons why an alteration requires years to be completed throughout the Fleet. Many can only be performed during a restricted availibility or overhaul period. In many cases, funding restrictions require that an alteration be delayed until a second overhaul period which would occur approximately three years later.

Fig. 4 shows the data for ORDALT 6865. This alteration was authorized for installation on February 1, 1969. As can be seen from the graph, the first ship to have the alteration completed was DDG-41 in April 1970, and the last is CGN-9 which is presently in overhaul. This shows that over a period of five years a configuration difference existed in 34 ships of a varying degree.

The AACP impact of this ORDALT is 6 engineering drawings in addition to those of other alterations and the basic system. For the outstanding ORDALT's on the MK-10 system, this number varies between 1 and 25. The impact on the CIIF is a listing of each drawing, the parts differences, and the relationship to the next higher assembly. The Class 1 Change File details all pertinent logistics and applicability data.

The MK-10 Launching System was used for this example because of its stable nature. As a system, it has undergone comparatively few changes and has been in the Fleet for a number of years. For complex electronic systems, such as the AN/SPG-55 fire control radar, the changes are more numerous and have a greater impact on the major files.

2.5 PRESENT PROBLEMS

In 1963 when the concept of configuration management was recognized as a viable management tool, NSWSES was primarily concerned with surface missile systems. At that time, the SMS fleet consisted of 5 aircraft carriers, 10 cruisers, 22 frigates, and 25 destroyers or a total of 62 ships. The SMS fleet has now expanded to 133 ships, and at present NSWSES has grown in responsibility and is engaged in a variety of systems; its files have expanded accordingly.

The greatest increase has been in the size of the CIIF, the AACF and its supporting MIF. Presently, the data shows that files are growing at a rate of approximately 250,000 line items per year. As these files become larger, they become increasingly more difficult to manipulate. Present software is based on file structure technology that is nearly a decade old and as such, lacks flexibility and is increasingly time-consuming to process.

The symptomatic problems caused by these characteristics are as follows:

(1) Increased file update time.

The procedure for updating requires considerable man-hours which results in approximately five weeks wherein the data of that file is not useable.

(2) Increased response time to users.

Because of the lengthy update cycle, user inquiries may be impossible to service until the data is processed. If the need is urgent, the user may be required to use the previous file information which is possibly in error. Users requiring tailored reports must be willing to wait until programming is made available for that specific format.

(3) Increased potential for error.

The files require a large amount of human operation. Even the most experienced operator establishes a finite error rate for a given volume of activity. Unfortunately, as the volume of transactions increases, so does the absolute amount of errors, even though the error rate might remain low. The result is that the update cycle becomes longer due to the greater number of errors.

(4) AACF.

Use of microfilm prints on aperture cards is more efficient and less time-consuming than handling full-size engineering drawings. But, because of the growth of this file, even this mode is requiring increased time. Departments that require the use of these cards send messengers to pick up the cards. The retrieval system is slow as it requires that each card be pulled separately with the use of slave decks and collators.

If a drawing is to be revised, it is obtained from the AACF, converted to hard copy, changed by the cognizant engineering department, redrawn by the draftsman, and reprocessed to the aperture card format. The average revision takes approximately 24 man-hours.

(5) Lack of file integration.

Although all files are related by various common data elements, there exist no means by which one file may interrogate or transfer data to another without the use of loading forms. For example, if an Engineering Change Proposal (ECP) has final authorization, it impacts both the Class 1 Change File and the CIIF. At present, elements of this change must be processed separately and by hand. The file relationships are shown in Fig. 5.

3. CONFIGURATION MANAGEMENT - THE FUTURE DEMANDS

3.1 BASIS OF PROJECTIONS

In the future, the magnitude of the problems discussed in Section 2 will vary directly with the volume of data which must be collected and stored and with the number and needs of the users of the data. In this section, changes are identified which will affect the volume and useage of the data management system at NSWSES in the future.

Determination of future demands on the data management system is based as much as possible on changes which can be predicted with relative certainty, such as the approved Navy shipbuilding program, on needs known to exist today, and on other events which may occur such as the expansion of the department's responsibility for configuration management.

If a computer system is to be installed, it could be in operation in the 1980-81 time frame, but since it must be capable of meeting the needs of the department several years beyond the installation time, some projections cover the 1980-85 time frame.

3.2 NAVY SHIPBUILDING PROGRAM

The Navy's shipbuilding program will affect the data management needs of the Technical Data Department in the future. The surface missile ships, which are included in the program, are of particular importance since the configuration of these ships includes many systems and equipments for which the configuration and data management divisions are responsible. Fig. 6 sets forth the Navy's shipbuilding program for surface missile ships through 1981 as approved by Congress. These numbers reflect a major effort which is planned for expansion of the fleet.

It is also important to consider the systems which are being installed on these ships and on ships which are already in commission. The projections for system deployment are based on recommendations made by the Anti-ship Missile Defense Project Office (PM-20). Fig. 7 lists several major systems for which NSWSES has the responsibility for some aspect of configuration and data management. The number of ships which currently have each system installed is contrasted to the number of ships anticipated to have the system installed in the 1980-85 time frame. The numbers in Fig. 7 therefore represent maximum numbers in 1980 when a new computer system could be in operation at NSWSES and probable numbers for system deployment by 1985.

The large increase in the total number of systems deployed will not cause a direct one for one increase in the demands placed on the data management system since the Technical Data Department will have varying degrees of responsibility depending on the system. However, the increase will be reflected in a significant increase in the data which must be stored and managed.

In addition, there will be a large increase in the number of users of the data since some systems will be deployed on a wide variety of ships where in the past the systems were largely confined to the surface missile fleet.

Configuration management will also be affected through expanded requirements to incorporate new data into the data base, particularily for new weapon systems which will require a large input of initial data. In addition, a relatively large number of engineering changes must be made rapidly during the test and evaluation and early deployment stages for new systems. The deployment of new systems also requires the development of proper parts support and the preparation of provisioning technical documentation.

3.3 NEW RESPONSIBILITY AREAS

3.3.1 Search Radars.

The department currently maintains the CIIF file for the SPS-58 search radar and tracks the location of several other search radars in the CSA site file. In the near future it is anticipated that the SPS-48 search radar will also be included in the CIIF file. There are currently 50 SPS-48 radar systems deployed which would cause a step increase on the data system demands followed by a more gradual expansion as more SPS-48 radars are deployed. The need for some source of configuration management of search radar systems will increase as these systems become more closely integrated with the weapon systems.

3.3.2 Gun Fire Control Systems.

The department is now involved in the configuration management of three gun fire control systems. This involvement resulted from the close coordination required when the MK-86 fire control system was undergoing test and evaluation at NSWSES and timely configuration changes had to be effected and documented. It is likely that additional GFCS will be incorporated in the future.

3.3.3 Underway Replenishment

The Commander Naval Surface Forces Pacific (COMSURFPAC) in April 1976 identified an urgent requirement for configuration control of underway replenishment (UNREP) equipment to the Naval Sea Systems Command. Although the exact form of configuration control to be used and the organization which will establish configuration management has not been decided, a logical choice to document and maintain configuration control is the configuration division at NSWSES. If the division were tasked with this responsibility using the current data management system, the accomplishment would be very slow and incremental due to the existing process for incorporating new data and the complete lack of configuration control which now exists on the UNREP ships.

The addition of UNREP configuration responsibility would in the long run represent a significant increase in data storage requirements. This would almost surely lead to a degradation of service to other users.

3.4 SUMMATION AND CONCLUSIONS

At the present time, the data acquisition process is tracked manually. The process could be followed much more efficiently with a computer based file similar to the Class 1 Change file used to track Engineering Change Proposals. However, the difficulty of creating a new distinct file under the current data management system makes the automation of the process unattractive. If an integrated data base existed, this data acquisition process could readily be automated.

The following is a recapitulation of variables which will impact both the urgency of need for an automated system and the specific characteristics of that system. Over the design, production, and installation phase of the system life cycle, these variables should be continually assessed to ensure that the end project will fulfill the requirements.

(1) Navy Shipbuilding Program - physical size of the Fleet

(2) System Development - number of systems maintained, number of system users

(3) New Responsibility Areas - change in user needs, change in NSWSES cognizant systems, change in responsibility for systems currently managed only in part

(4) NSWSES personnel manning levels - need for increased productivity

The total impact of the above variables on the problems identified in Section 2 must be considered by NSWSES in the justification for and the development of a modernized data management system. The variables which have been identified are general in nature. However, based on the trend of these variables and the close observation of the operations at NSWSES, the need for a modernized data management system is indicated. It is recognized that before a formal request for a modernized system is made, specific data must be gathered to support this general conclusion and to define the parameters of the system requested. It is felt that the specific data will support the need for a modernized system. The following section provides the basic system definition that will be required to fulfill NSWSES future requirements.

4. SYSTEM CHARACTERISTICS

4.1 SYSTEM DEFINITION

The system specifications must be based upon a clear definition of what the system must accomplish, i.e., an interaction of user needs and technological capabilities. It is rooted in the variables described in Section 3 and, therefore, must remain general enough to respond to their change but must be specific enough so that a dialogue exists to facilitate technology response to the need.

First, the system required must marry the functions of data and configuration management. To facilitate this, some type of computer system will be needed with the capability of quick response to inquiries and ease of updating and inserting data. These considerations would indicate that the systems should be on-line vice batch in nature. This requirement can be fulfilled in two ways: 1) a large computer where NSWSES personnel would be tenants in a multiprocessing system or 2) a minicomputer maintained by the station and specifically dedicated to ICMDS. Because the requirements of NSWSES are not only data processing but interactive control between analog devices which must perform operations in various output media (e.g., microfilm production), the second option of having a dedicated data handling device such as a minicomputer would be more suitable. This defines the first area of technological review.

The major output of the Configuration Management Branch, other than hard copy reports, is microfilm packages which are used by both shipyard and Fleet personnel. These are produced from the aperture cards that are filed in the AACF. The bulk of the AACF has been previously discussed as a critical factor in the time required for distribution of microfilm packages. A technology that has emerged in recent years is the process of converting engineering drawings to a digital format and storing the information on magnetic tape or disk. If feasible, this process would allow computer controlled microfilm production and significantly reduce the physical storage requirements of the AACF as well as the number of personnel required to maintain it. It would also facilitate the acquisition of drawings in digital form and reduce the amount of hard copy.

Inherent to the concept of digital storage of drawings is the capability of projecting the drawing on a CRT input/output (I/O) device for the use of engineering and quality assurance personnel. This would allow engineering personnel to query the CIIF for the latest revision of the drawing needed and call the display from a terminal. Once the section of interest is displayed, hard copy could be produced if required.

A follow-on to display of digitally stored drawings is the concept of automatic drafting. If a drawing is to be revised by station personnel, the process might be done by a computer controlled drafting system with preprogrammed standard functions. This would allow drawing updates to occur within a matter of minutes instead of the 24 manhours now estimated. Final drawings should pass the same quality assurance tests which drawings received from contractors must pass.

The issue of support equipment should now be addressed as it will ultimately impact the actual configuration of the system. The computer system includes two additional considerations: 1) the type of I/O devices required and 2) the storage facilities. The type of I/O device will vary between functional areas. The terminals required by data and configuration managers will differ from those required by engineering codes. Therefore, a review of the "intelligent" terminal technology is in order.

Because of the possibility for digital drawing conversion, the total storage requirements for the system may become quite large. The actual size will depend upon the portion of the AACF that will be digitized. The issue of storage devices becomes a tradeoff between mass storage systems with a small amount of operator interaction and conventional disk and tape storage with the operator drawing the file from a library system and mounting it as required. The overriding consideration in making this tradeoff will be that of system access time.

The preceding section included a general definition of the system characteristics and derived the areas of technology in which to start the initial review. This relationship is summarized as follows:

(1) Central Processor - Minicomputer

(2) Automated Microfilm Packages - Computer - Output - Microfilm (COM)

(3) Retrieval and revision of engineering drawings - Digital Storage of Drawings, Automated Drafting

(4) Support Equipment - "Intelligent" Terminals, Mass or Conventional Storage Devices.

4.2 TECHNOLOGICAL SURVEY

Following is an initial survey of the specific technologies addressed in the system definition. Mention of specific brand names are kept to a minimum. However, in some cases, a particular approach is best exemplified by a specific manufacturer are listed by suggesting the characteristics of their systems as they pertain to the areas of interest.

4.2.1 Minicomputers.

Minicomputers first became an important part of the computer community about 1965. With essentially no sales in that year, the minicomputer industry had grown to over $300 million annual sales by 1973, and continues to grow at a rate of 20 percent to 30 percent per year. Though total sales figures may vary significantly, minicomputers still represent only a small portion of the $13 billion total market in the United States for computer products and services. Nevertheless, the minicomputer segment is expected to continue its rapid growth with estimates of worldwide computer market volume soon to reach an even $1 billion.

Digital Equipment Corporation, the company that started the minicomputer boom in the mid-sixties with the highly successful PDP-8 line, is still undisputed king of the minicomputer field. Rounding out the "big six" among the minicomputer builders are Honeywell, Hewlett Packard, Varian, Data General, and Microdata.

The second rank of minicomputer makers comprises the aggressive, innovative young companies such as Computer Automation, Digital Computer Controls, General Automation, and Interdata. Minicomputers are also being built by divisons of well-established conglomerates such as General Telephone and Electronics, Lockheed, Raytheon, Texas Instruments, and Westinghouse.

As might be expected, IBM gets a category unto itself. The undisputed leader in most other segments of the computer field is still playing a comparatively minor role in the minicomputer field. However, its very latest entry, System 5100, will undoubtably aid in giving IBM a large percentage of an industry it heretofore chose to neglect.

In all, more than 80 companies are now marketing minicomputers in the United States. The current offerings of these companies include more than 200 minicomputer models.

The following basic trends appear to be emerging:

--The minicomputer is increasingly becoming part of a much larger hardware, instrumentation, and control system.

--The serious computer manufacturers are gearing their design and marketing strategies to selling to original equipment manufacturers, systems houses, large-scale computer manufacturers, communication companies and myriad large and small business enterprises.

--The potential user has a wider choice, is more cost-conscious, is more aware of the additional requirements of minicomputer systems and is willing and able to start small in an effort to grow large.

--Prices will continue to fall as a result of technological improvements and aggressive competition. These fundamental points are the result of the following changes: reduction of processor and memory costs; greatly increased reliability and flexibility; increased availability of operating, application, and support software; increase in the use of read only memory and microprogramming; improvement in hardware and software design; and increase in experience gained by using minicomputers successfully in a range of applications.

4.2.2 Computer-Output-Microfilm (COM).

Computer-Output-Microfilm is an information system that converts computer data into readable form on microfilm. COM first appeared commercially in 1959 by such companies as Stromberg DatagraphiX, IBM, Eastman Kodak and Data Display Incorporated. These devices were mainly CRT printer-plotters intended for administrative and engineering applications. But their marketability was uncertain and shortly IBM left the field and has never returned.

COM is a microfilm camera backed up to a computer. In its most basic operation, a COM system takes the digital signals recorded on magnetic tape or coming directly from a computer system, runs them through a logic section to determine their locations, converts the signals into an electronic beam and projects it onto a CRT screen. A special camera then takes a picture of the CRT screen at specific intervals and records the contents on film.

COM recorders have been produced that operate both on-line and off-line from the host computer. On-line COM devices are connected directly into a speed paper printer. Because of this, no modification of the host computer's program is generally required when an on-line COM recorder is used. Off-line COM systems receive the computer output on magnetic tape. On-line COM recorders might be somewhat cheaper, since they do not include an input tape drive. However, the off-line method offers more compensating advantages, such as increased speed which significantly reduces computer time and expense; reruns of the COM operation do not require computer time; and the ability to use a number of microfiche titling and indexing techniques which are impractical with on-line COM.

4.2.2.1 Transfer techniques. The CRT technique is the oldest and most commonly used method for COM recording. An electron beam draws the desired characters on the face of the CRT. The image of the character passes through a semi-reflective mirror and lens system onto the unexposed film. After a page is exposed to the film, the film is advanced, and the next page of information is displayed on the face of the CRT. If desired, the image of the form used when generating the report on a computer high-speed printer can be superimposed on the film. This is accomplished by flashing a bright light behind a glass or film slide on which the image of the form has been photographically reproduced. Through the use of a semi-reflective mirror, the form's image passes through the lens system onto the film. An alternate technique involves the use of a programmed merge, and requires the drawing of the form around the data on the face of the CRT by the electron beam.

EBR, unlike the CRT technique, writes directly onto the unexposed film with the electron beam. To properly control the direction of the electron beam, this process must be performed in a vacuum chamber. Unexposed film is drawn into the chamber, and a page of information is written onto the film. After the page has been completed, the film is incremented, and the next page generated. With EBR technique, if a form slide is desired, its image is placed on the film by the use of a second lens system after the data has been written on the film. One of the main advantages of the EBR technique is that a special type silver film can be developed by heat rather than wet chemical processing.

LBR writes directly on dry silver microfilm forming a latent image that is developed by heat, not chemicals. The laser is expanded through a beam-expanding telescope. Then, it is deflected through an acousto-optic modulator to form seven beams which write at high speeds directly on the film.

The LED technique directs its digital signals to a bank of light-emitting diodes through a character translation matrix. Light from these diodes is transmitted through fiber optic strands to form an image. An entire line is thus formed, displayed and photographed via the fiber optics assembly. The film is then advanced one line at a time. The forms overlay process is accomplished by use of a second lens system, as used in the EBR system. LED has two limitations: 1) in the microfiche production, there is difficulty in controlling the movement of the film and 2) because LED emits red light, red-sensitive film must be employed with special filtering processes producing a less sensitive process with inferior resolution than blue-light sensitive processes.

4.2.2.2 Film types. There are four types of film utilized in the COM process. The majority of the industry has chosen the silver halide film for making the master copy; the most popular brand is the Kodak Dacomatic. The silver halide film is known for its inherently wide tonal range and its contrast range satisfies most specifications. In addition, a silver halide film specimen has been known to last over 50 years without showing signs of deterioration, an important characteristic for archival mediums. This type of film produces a negative or reversal image. There are, however, several limitations. Most annoying is the requirement for wet chemical processing, involving several baths and roller devices. This type of film is also subject to easy scratching. Finally, the price of these films is quite high.

Diazo film is much less expensive than silver halide film and is used widely for microfilm duplicating. The film contains dyes which produce a visable image when exposed to ammonia vapors and a strong ultraviolet light. Unlike silver film, diazo film is non-reversing. Its cost is low and it gives a highly satisfactory duplication with excellent contrast. It does have the drawback that ammonia vapors require special ventilation and create an unpleasant working situation.

Vesicular film is a comparatively recent development which is competing hard against diazo. Transparent crystalline particles are mixed with a transparent resinous plastic, coated onto a mylar base, and exposed to ultraviolet radiation. To develop the image, heat is applied. The process is reversing. The finished vesicular copy is very sturdy and scratch resistent. A disadvantage is that if the exposure to ultraviolet light in the duplicating process is not sufficiently prolonged, the images will tend to darken over a period of time.

Dry silver film is a 3M product used on the 3M FBR and LBR COM. A latent image is formed by the electron or laser beam writing directly on the film, and then developed by heat, not chemicals.

4.2.2.3 COM hardware. Some of the more expensive COM recorders have built-in minicomputers to control their operations. The primary function of this internal computer is generally to reformat the input data prior to recording on microfilm. By utilizing this technique, the mainframe computer is relieved from the task of reformating and coding. Minicomputers are mostly used in graphic applications or when special instructions are required for titling and indexing the fiche.

There are other pieces of equipment involved in COM systems. These include:

(1) Magnetic Tape Unit - Most COM systems include in their purchase price a magnetic tape unit for input into the system. The Memorex 1603 appears to be the only system currently available that does not. The majority of the tape drives accept 7 or 9 track tape at 556, 800 or 1600 BPI.

(2) Microfilm processors - With the exception of the 3M Dry Silver Film, which is developed via an internal heat process, all COM original film requires some "wet" chemical processing. This process can be accomplished either through the use of a separate film processor or through the use of an internal processor.

(3) Microfilm Duplicator - Microfilm duplicators make multiple copies of microfiche or microfilm for distribution. A variety of models is available, from the DatagraphiX Model 71 table-top unit which operates at 360 fiche per hour, to their Model 75, which has a through-put speed in excess of 1000 copies an hour and which collates up to 100 sets automatically.

(4) Microfilm Readers/Printers - There are many styles and types of readers and their price range varies from $175 to $400 for microfiche. Microfilm readers are more complex and range from $400 to $1750. The majority of readers function quite satisfactorily. However, some portable models have problems with illumination and optical distortion. Reader/Printers give the added advantage of being able to produce a hard copy of the page desired on a selective basis.

(5) Automatic Retrieval Devices - Devices are available to permit the selection and insertion of a fiche into a fiche reader in a matter of seconds. This has the advantage of speed and simplicity of accessing large amounts of information. The major disadvantages include the cost of the retrieval devices and the additional fiche production time required to prepare the fiche for insertion into the reader.

4.2.2.4 Other considerations. In addition to the physical specifications of COM equipment, one must take into consideration the requirements and the exact output functions expected to be derived from the COM system--data file size, frequency of update (should be no more than once a day) need for hard copy, number of locations requiring copies of reports, and the retrieval requirements; whether the COM system will be on-line or off-line; costs for utilizing COM equipment which may increase due to inflation and greater sophistication; total cost per line of copy; the timeliness of the information; convenience and availability of output.

4.2.2.5 Future trends. The industry is experiencing incredible growth. A survey conducted by International Data Corporation determined that the COM industry would double in the next five years.

As far as technical improvements, the "Ultrafiche" has great promise. Also called Photochromatic Microimage (PCMI) Technology, ultrafiche gives a high density fiche on the order of 96X reduction and can reverse color based on temperature or specific radiant energy. As a result, the image can be changed (in contrast to the silver halide film), producing a perfect master at less cost and time delay. This will be particularly applicable to graphic requirements. Ultrafiche is limited because it requires careful balance of quality control, sensitive readout equipment and high volume.

Another innovative technique is Computer-Input-Microfilm (CIM), which is a scanning technique in which the image on microfilm is scanned and stored as computer records. Such systems have most commonly been applied to engineering development applications and are not widespread at this time.

Finally there is a current trend toward front-end processors because of their flexibility.

4.2.3. Digitalized Drawing and Automatic Drafting

One of the rapidly developing areas of computer technology is the storage of engineering data in digital format. The digital storage of an engineering drawing offers several advantages including automated drafting systems; reduced storage space; the ability to reproduce clear and accurate drawing copies; reduction in the amount of hard copy used; numerical control of the manufacturing process; a choice of outputting digital data to hard copy, microfilm or CRT for display or interactive operations; maintaining the data base through interactive terminals.

One problem which still exists with digitized storage of drawings is the slow rate at which current hard copy can be converted into digital format.

4.2.3.1. The designer system. The Computervision Corporation Designer System is described below to provide an example of the application of current technology in interactive graphics.

The Designer System is a complete automated system that can integrate a development effort from the first design idea to the finished product. The engineer and designer interact with the system through CRT devices or plotting surfaces. The system provides computer aided design and production.

The Designer System offers an autoscan operation which can input data from hard copy at approximately four square inches per second. It offers interactive plotting surfaces which allow drawings to be digitized into the system or plotted out on the surface. In addition the system provides interactive CRT terminals with two or three-dimensional displays.

The central processor for the Designer System is a high-speed, general purpose minicomputer with up to 128K 16-bit words of main memory, supported by cassette tape, magnetic tape, disk memories of up to 14 million word capacity. A single central processor can typically control four or five interactive terminals.

It is almost certain that many companies and the government will go to digital engineering data bases which will make interchange of engineering drawings in digital format entirely possible. The automated drafting function is well developed today and is operational in several companies. Refinements to the automated drafting systems can be expected over the next few years.

4.2.4 Mass Memory Systems

The need for mass memory systems in the range of 10^{12} bits has become evident with the advent of increasing dependence on computer information management systems in business and scientific endeavors. The ideal system, allowing random access of 1 μsec with a reasonable price, has not yet been realized. Presently, non-random access systems are available which provide for mass storage at a reasonable cost per bit.

While moveable head magnetic disks offer access time advantages, even the latest IBM-3330-11

(2000 Mbyte capacity) disk does not lend itself to mass storage application. The primary constraint is the physical limitation of head alignment and the necessary decrease in distance between head and tape for higher densities. Increased effort in overcoming these mechanical problems has had limited success resulting in the elimination of this method from consideration in mass memory systems.

Other storage systems which may be considered are the UNICON 690-212, manufactured by Precision Instruments; MASSTAPE, manufactured by Grumman; and Tera Bit Memory (TBM), by AMPEX.

The UNICON system has a total capacity of 0.7×10^{12} bits. Storage is on data strips in a carousel. The system contains independent read/record units which provide for a simultaneous read/write capability. Access time for this system is approximately 10 seconds. A Recorder Control Unit (RCU) using a minicomputer for overall control of the memory system provides interface with the host computer.

The Grumman system offers storage of 10^{12} bits and an average random search time of less than six seconds. Storage is in cartridges in a carousel. Eight storage units are controlled by a masstape controller (minicomputer). The system provides for allocation of up to 16 active files with a burst transfer rate of 10^6 bytes per second.

The TBM system boasts one of the largest capacity figures of 3.1×10^{12} bits. Reasonable access times are provided by use of video recording techniques which allow search speeds of 1000 ips and up to six simultaneous searches or the equivalent of 60 conventional computer tapes per second.

A summary chart of these three systems and a conventional comparison is shown in Fig. 8. More detailed information on these systems can be found in reference 1.

4.2.4.1 Filing and transfer methods. Most systems are designed for sequential access using large data blocks, which significantly reduces efficient random access to a relatively small data set. The recording media is "control software" subdivided into "allocation units." Physical storage space is made up of an aggregation of allocation units. Selection of the size of the allocation unit is a compromise between space and processing efficiency and is also a function of the intended user application. Increased random accessing would imply larger unit size. However, up to 33% of storage capacity may be unused due to average user data block size. Since even the best access times are too slow for numerous random access requirements, most manufacturers use compromise allocation units of approximately 130 Kbytes.

User files can be transferred from the mass media either directly or by staging. The direct transfer mode of operation requires allocation of a data path for each active file to each host, whereas, staged transfer requires only one data path for all files. Additionally, that path must remain dedicated during processing execution and the file must necessarily be processed sequentially. While staging requires host or shared hardware, after the file has been staged it may be randomly processed if the file has been staged in its entirety. Again, particular software must be tailored for individual requirements.

Selection of a particular file processing technique must include consideration of the file activity ratio. Very low activity ratio files would favor direct access. High activity ratios would indicate a batched input and sequential access. The latter is envisioned as the most prominent mode of operation.

4.2.4.2 Disadvantages. One of the disadvantages of mass storage systems is their high expense; although, this is not the primary obstacle to their widespread use. A more substantial problem is the uncertainty involved with any new and untried system, particularly expectations of technical problems. However, probably the most significant obstacle to widespread utilization of mass storage systems is the excessive random access time.

Systems such as UNICON which utilize non-erasable, laser recording techniques certainly provide an excellent archival media, but are less flexible for numerous record processing changes. In research related to their own application developments, Ampex has found that after a file has been inactive for three months the probability is less than .5% that it will again be accessed. This is quite different from the NSWSES operation where 95% of the AACF cards are accessed in 5 years, 75% in 2 years, 50% in 1 year and 20% in 3 months. This would indicate a significantly more active system and possibly result in a greater man-hour cost savings if automated.

Finally, the pay-off for conversion to a mass storage system does not occur for at least five years, which leads to the very real risk that technological improvements will render the system obsolete and reduce the returns of a sizable capital investment.

4.2.4.3 Advantages. There are a number of positive factors characterizing mass memory systems. They offer obvious economic advantages in cost-per-bit as compared to conventional methods of on-line storage. Additionally, they feature handsoff data retrieval, relieving many scheduling and librarian costs/problems and security against data loss and overwrite risks inherent to the often piecemeal conventional library techniques. Many utility functions may be accomplished with some systems in an off-line mode or independent of the host computer. The physical size reduction of mass storage facilities over conventional systems for a given storage requirement essentially eliminates the requirement for bulky off-line tape libraries. The modular add-on design of most systems allows for capacity/performance changes as requirements change. Finally, the data throughput rates are comparable to conventional storage media making them quite competitive in sequential processing applications.

4.2.4.4 Future mass storage. In this area there are almost as many predictions as there are predictors, but a representative sample is offered here.

<u>Charge coupled devices</u> utilize much the same technology as MOS devices, but remain unattractive for mass memory applications due to their volatile storage process, despite many desireable features (e.g., fast access times).

<u>Magnetic bubble devices</u> have essentially been three years from production for the past five years. Using present technology they too are relatively volatile in that a small D.C. voltage must be maintained. However, Rand Corporation predicts that by 1980 bubble technology advances will result in a nonvolatile system with a 2 μsec random access time and a density figure of 10^6 bits/in^3 for 0.01 cents/bit.

<u>Electro-optical</u> techniques encompass both electron beam and laser technology, as well as several radiation sensitive media (i.e., thermoplastics and photochromic). Electron beams can be focused for extremely high potential density rates, but must operate in a high vacuum which limits their application possibilities. Laser beams can operate in normal environments and can be focused with several mechanical and nonmechanical means.

<u>Holographic techniques</u> entail the recording of optical wavefronts formed by the interaction of a reference laser beam with a second reflected beam. In erasable media, heating above curie temperatures and a magnetic field can be applied in 15 to 20 μsec, but upwards of 100 kwatts of power is required. An entire page of data could be recorded simultaneously further speeding the process. Reading is accomplished by illuminating the recording with a light beam and reflecting the light on an array of photo conductors. Time required is less than 10 μsec.

The most far reaching predictions come in the area of laser applications. For instance, Laser Computer predicted a system utilizing a 4x4 foot thin film plane with a capacity of 10^{13} bits with a maximum access time of 20 nanosec and a transfer rate of 50 Mbits/sec. The cost was to be 2×10^{-5} cents/bit. Further characteristics were nonvolatility for greater than 25 years, less than one error per 10^9 bits, associative memory organization, no moving parts, plug-in capability with IBM peripheral equipment, and with a price of less than $1.2 million. Phenomenal predictions such as systems with capacities of 10^{40} bits have been forthcoming from the same source. These systems are to feature access to 1000 bits in less than .3 nanosec. Unfortunately, very few specific details of any significance have been forthcoming since the initial announcements. Furthermore, a few calculations indicate even with the speeds predicted, a total of 10^{21} years would be necessary to access all the memory in the 10^{40} bit capacity system.

While such announcements are rather over-optimistic and deserving of skepticism, predictions by numerous credible authorities have been extremely encouraging. For instance, by 1983 another predictor asserts that a moderate speed device utilizing a disk with holographic or cryogenic technology will have up to 10^{14} bits/units capacity, an access time from .01 to 100 msec, and a price of $6x10^{-6}$ cents/bit. Still other more skeptical individuals predict present motion of media techniques will be necessary for the foreseeable future. Current mass memory systems require motion of the media past a read/write device due to the present recording density technology. Therefore, access time is relatively poor which essentially negates the practicality of random access processing. This results in many users with relatively large storage requirements such as Aetna using conventional storage devices at a considerably higher cost/bit.

In summary, while mass storage systems are useful for archival means, that characteristic is not an important selling point in most instances. The application of these systems is relegated generally to batched input and sequential file processing in applications which require a large data base (greater than 10^{11} bits) on line. Further they would normally supplement conventional devices, as part of a hierarchical system rather than replace conventional equipment entirely.

Numerous problems were expected in initial installations and indeed they materialized in most cases. Most mass storage manufacturers conceded the system would be difficult to obtain, but it is extremely unlikely that any one vendor has sold more than 12 units in the past five years.

Future technological breakthroughs in developing fast access, high density storage media are a certainty. It may be a non-moving media device as is envisioned by Laser Computer Corporation or a disk-type system as envisioned by more moderate predictors.

4.2.5 Intelligent Terminals

On-line computing systems are designed to use terminals and telecommunications links to overcome the limitations of batch processing systems. Strategically, a terminal can be an interactive device which enables the user to communicate with a computing system at a record level, rather than at a file level; it may be a device which transmits and receives batches of data quickly and accurately to and from a computer; or it may be a device which has intelligence of its own and is able to perform certain tasks itself, thereby relieving the main computer and reducing the load on the transmission line. Any type of terminal may be provided with some level of intelligence.

The benefits of relieving the main computer are that the computer is better able to give fast response to messages, is better able to handle peak loads, and is freed to do other work. As a consequence, costly storage additions to the central computer can be averted. The benefits of reducing the load on the transmission line are that less errors will occur and that transmission costs may be reduced.

An intelligent terminal generally consists of components of an interactive terminal; processing unit capable of executing conventional computer instructions; high-speed memory for storage of both data and operational programs; and mass storage, typically cassette or cartridge tape; and conventional or floppy disks. A program can be entered into the programmable read only memory

(PROM) area where it cannot be altered. On some terminals, a board containing logic circuits can be unplugged and replaced by another.

Compared with equipment which would have had the same capability of just a decade earlier, an intelligent terminal is incredibly small in size, reliable in use, easy to maintain and to repair. It is easy to use because it can be programmed to provide different levels of man/machine dialogues depending on the application and the person using it. It provides aid to operators in local editing of entered data with page buffering and a fill-in-the-blanks screen format. In general, intelligence is put in a terminal for communication, for bulk memory control, and for operator assistance.

Intelligent terminals can check and validate data prior to transmission. They can pull information off local storage, upgrade it and use it as required.

The intelligent terminal is essentially a single key-entry station which has the capability to support various peripheral devices including random access devices being used concurrently with data entry. When a large number of key entry devices are required at a single site, the cost of intelligence needs careful analysis. To overcome disadvantages in this situation, some vendors have incorporated the concepts of intelligent terminals in clustered versions. In these systems each display can perform as an independent intelligent terminal with respect to user-programmed data entry. Multitasking software allows data entry to run concurrent with processing and communication.

Some of the more sophisticated on-line distributed processing systems are capable of continuing processing data at the local level for some time even when the communications link is down, or if the host computer is not operating. On-line updating is then done when all facilities are once again functional.

In other distributed processing applications, a remote intelligent terminal acts as a stand-alone processor during daytime business hours. The terminal is polled by the central computer at night to collect data and update the data base before the next workday.

Until recently most intelligent terminals could not perform simultaneous operation of printers, cassettes, card readers, etc., or permit their being shared by two different terminals. In other words, if the terminal was busy printing, it was unavailable for input.

Three developments have practically eliminated these restrictions:

(1) High-speed microprocessors with a cycle time of one microsecond or better,

(2) changes in architecture design which allow direct contact between the terminal's internal memory and the peripherals at memory speed,

(3) parallel connection of peripherals on the same line with the terminal by high-speed data buses. These buses have allowed up to eight devices to be connected to the intelligent terminal at distances up to 7000 feet. Data transfer occurs at speeds up to 20,000 bytes per second.

More advanced terminals of the future will likely require less interaction with the main computer. Additionally, features will be installed which will reduce operator interaction and lower the possibility of errors.

4.3 TECHNOLOGICAL IMPACT ON SYSTEM DEFINITION

Most of the areas surveyed hold great promise in satisfying the specific requirements of the system definition. Therefore, little change will be presented here. The minicomputer industry is well along in production of machines which can adapt to data base management as well as interface with other components such as COM devices. The production of more advanced "intelligent" terminals can provide flexibility for operator interaction with the main computer as well as relieve the main computer of many of the more tedious chores. Other I/O devices are also becoming more sophisticated and require less main processor time for control.

The only technology area which appears to be somewhat questionable is that of mass storage systems. Developments in this area appear to hold great promise but at present, technical interface difficulties might preclude immediate use. This is not to eliminate the possibility of their use but to emphasize that particular attention must be paid to this industry when future iterations are made and the impact on the system definition is assessed.

Perhaps the most critical issue derived from the survey is that of interfacing the various devices into a system. All facets of the computer industry appear to be making great strides with new innovations emerging almost weekly. But, with this accelerated progress, increasingly more emphasis must be placed upon efficient system design.

4.4 OPERATIONAL SYSTEMS

To develop an appreciation for the approach of other organizations to configuration and data management and to observe the application of current technology, the configuration and data management systems at the Pacific Missile Test Center (PMTC), Point Mugu, California, and at Lockheed Missile and Space Company, Inc., Sunnyvale, California, were observed. Although there are some variations in each configuration and data management system, the problem of configuration control is universal enough that standard software systems have been developed which could fill NSWSES configuration control requirements.

4.4.1 A Navy System

The Pacific Missile Test Center at Point Mugu performs the configuration control function for systems under the cognizance of Naval Air Systems Command which is a mirror image of the configuration control performed by NSWSES for systems under Naval Sea Systems Command. This commonality of functions makes possible a direct comparison of the configuration management requirements of the two stations. This is particularly pertinent since PMTC has an on-line system for configuration management in operation which is very similar to the system envisioned at NSWSES.

The Configuration and Data Management Support System (CADMSS) at Point Mugu serves both PMTC and the Naval Weapons Center (NWC) at China Lake, California. It provides on-line query and a data collection system supporting in-service engineering, logistics, configuration and data management. The system is accessed via IBM 3270 compatable data collection stations capable of storing and retrieving management data information. The data stations are linked to the CADMSS data base via telephone network.

The processor is an IBM 370/165 and supporting telecommunications. This system receives, processes and stores data from the CADMSS data stations, and retrieves queried information and generates selected reports for a particular data station.

The CADMSS is comprised of four interacting modules utilizing common data bases.

The Technical Data Module (TDM) provides for the identification and control of technical data and for the accounting of changes to the data. Standard on-line query, data entry, and file maintenance techniques service the TDM. Data edit and validation are included in file maintenance routines. On-line query capabilities relate the current revision status of all technical data on file and the status of in-process changes to the technical data on file.

The Contract Monitoring Module (CMM) tracks contract data requirements and hardware deliverables. Data edit and validation are included in all file maintenance routines. On-line query and hard copy report capabilities relate the status of Contract Data Requirement deliverables, hardware delivery status of configuration and items by serial number and contract baseline. The contract baseline information is retained in the parts bill-of-material format for each contract, thus providing a baseline accounting for a specific contract.

The Baseline Accounting Module (BAM) provides a bill-of-material process from which product base-lines of equipment are extracted. Data edit and validation are included in all file maintenance routines. On-line query and hardcopy report capabilities relate the baseline definition, component usage, contract baseline definition and contract component usage.

The Change Accounting Module (CAM) tracks the status of all Engineering Change Proposals, deviations, and waivers. The approval cycle status of a change is monitored by date and activity. The impact of a change on other portions of the CADMSS system is provided by the linkages of technical data affected, parts affected, including contract baseline and contracts affected.

The CADMSS was developed as a structured system utilizing a standard data base to provide accurate and timely information. The system was designed with the flexibility to grow to meet future requirements with minimal impact to the basic system and provides data validation, ease of maintenance, rapid data retrieval, flexibility in operation and integration. The CADMSS was designed to minimize training requirements for effective utilization of the system. Specialized training or experience is not required for normal system use. A menu technique of accessing system functions is utilized to minimize requirements for familiarization with specific program names. Operators follow normal sign-on procedures including password security. After sign-on, the CADMSS executive system directs the program selection based on descriptive names rather than coded program identifiers or numbers.

The automated functions of the Technical Data Module and Contract Monitoring Module described above for CADMSS correspond very closely to many of the responsibilities of the Data Management Division at NSWSES. These functions at NSWSES are currently carried out manually but as demonstrated by tne CADMSS system, many of these functions could be automated for a much more efficient and effective operation.

The Baseline Accounting Module and the Change Accounting Module described above for CADMSS correspond to the CIIF and Class 1 Change File respectively as described in Section 2. The on-line feature provided by CADMSS provides a vast improvement over the batch operation used at NSWSES.

The Point Mugu CADMSS system appears to provide an excellent example of an operational on-line system which could be utilized by NSWSES in the development of the specifications for their own system.

4.4.2 An Industry System

The Configuration Accounting System employed at Lockheed Missile and Space Company is primarily concerned with insuring that the "as built" systems are reflected correctly by supporting technical data upon delivery to the Navy. The configuration control required at NSWSES is primarily concerned with maintaining control after systems are delivered to the fleet. However, review of Lockheed's Configuration Accounting System revealed that configuration control systems are very similar regardless of the specific application. Desired features of particular configuration systems available in industry could be incorporated in the specification of a new system at NSWSES.

Review of the Lockheed installation did provide an opportunity to observe the operational application of the digitized storage of engineering drawings and an automated drafting system based on this digitized data.

The Computer-Graphics Augmented Design and Manufacturing (CADAM) system at Lockheed is independent of the Configuration Accounting System. The CADAM system is designed to operate on an IBM 360 or 370 computer, but automated drafting systems are adaptable to minicomputer applications. The system can support up to 14 interactive terminals with 130,000 byte region of core memory without a noticeable reduction in response time. A reduced number of terminals would reduce the core memory requirements.

The CADAM system automatically controls release of drawings and prevents unauthorized changes. A key code is input into the program which is acessible only to authorized individuals. The master digitized drawing file is kept current with a minimum of man-hours effort. The ease with which a digitized drawing can be updated and the automation of the drafting functions show promise for substantial cost and time savings. In addition, looking to the future when the military specifications may allow the acceptance of engineering drawings in digitized form makes the consideration of a system such as CADAMS attractive from both a cost and space savings aspect.

4.5 OPERATIONAL SYSTEMS IMPACT ON SYSTEM DEFINITION

The review of operational systems provided a valuable input to the system definition. The CADMSS system at Point Mugu is fully specified and operational and many of the problems associated with the development of a new system have been solved. Other problems which may arise will be resolved before the NSWSES system goes on-line and as its system definition is firmed up, NSWSES should take advantage of the knowledge gained at Point Mugu.

One important difference between the Point Mugu system and the system envisioned at NSWSES is that the CADMSS system was designed to operate as a tenant on an IBM 360 computer and the system at NSWSES will most likely utilize minicomputers as the central processing units. This is because the minicomputer industry has made great strides in satisfying the needs of a data management system since the CADMSS system at Point Mugu was specified.

Another area from which NSWSES should take full advantage of available knowledge is the area of digitized storage of engineering drawings and automated drafting systems.

As they develop and finalize their system definition, NSWSES should continue to review the operational systems.

5. ACQUISITION PLANNING

5.1 RECOMMENDED ACQUISITION PLAN

NSWSES should acquire an automatic computer based configuration and data management system in a time phased sequence. Completion of each phase will result in the defined capability being obtained. It should be noted, however, that the phases are not independent and some decisions must take into account the requirements of all phases. Also, decisions made in each phase will limit to some extent decisions which can be made in later phases. Another key factor which ties the phases together is the timing of various segments in each phase. Fig. 9 gives the overview of the recommended acquisition process and the following paragraphs provide more details of the process.

5.1.1 Phases of Acquisition

PHASE 1 - Integrate the Configuration Item Identification File, the Site File, the Class 1 Change File and the Master Index File into a common data base. Develop a Technical Data Tracking File for technical data requirements similar to the Class 1 Change File for Engineering Change Proposals. Acquire the central processing units, the interactive terminals and the software operating systems necessary to develop an on-line configuration management system operating on an integrated data base.

PHASE 2 - Develop the capability to digitally store engineering drawings and the capability for computer output to microfilm. This phase will greatly increase the storage requirements over phase 1 and will require either a mass storage system or a library system. In addition, input digital scanners will be required.

PHASE 3 - This phase is a natural follow-on to phase 2 and involves the development of the digitized display of engineering drawings and an automated drafting system. Phase 3 would primarily provide services to NSWSES departments outside the Technical Data Department and would involve both hardware and software for the automated drafting system and display terminals.

The recommended phases of procurement were selected to provide the maximum benefit from the new data management system as early as possible in the system development and to delay the acquisition decisions which are less clearly defined at present until a later point in the sequence. Phase 1 in the acquisition process does not require any technological accomplishments that do not already exist today. In addition, software systems are in existence which can easily be adapted to the phase 1 requirements. Completion of phase 1 would provide a major improvement in the configuration and data management system of the Technical Data Department. Completion of phase 1 will give the department complete in-house capability with regard to their configuration and data management system and will make the progression to phase 2 much easier and reduce disruption of services.

Phase 2 will provide the Technical Data Department the capability to meet the long-term future demands which will increase as the volume of data and number of users increases. However, before phase 2 can be implemented, some problems must be resolved and some technological questions answered. Currently the military specifications do not allow the acceptance of engineering drawings in digital format. Some digitized drawing systems do not provide the specified resolution. To determine the full potential of a digitized engineering drawing system it must be determined to what extent the contractors and other organizations which interface with NSWSES will convert to similar systems which would allow the interchange of engineering drawings in digital form. In addition, it is not certain at the present time that the technology of the mass storage systems or a library system would provide the response time that would be required to maintain the engineering drawing file.

Phase 3 would provide the logical benefit available once phase 2 is complete. Phase 3 does not pose any particular technological problems but implementation of phase 3 will call for close coordination within NSWSES since other departments will effectively become tenants of the Technical Data Department's system and questions of response time, priority systems, etc., become important.

5.1.2 Acquisition Timing

The establishment of a timing sequence similar to that shown in Fig. 9 serves three major functions. First, this will allow for an orderly sequence of procurement which can be merged with the budget cycle. Second, the attainment of various operational objectives can be anticipated. Third, and perhaps most important, the assessment of one phase can be used to influence decisions in the contract definition of the subsequent phase thereby providing a total system which most nearly meets the overall operational objectives.

5.2 RECOMMENDED ORGANIZATION PLAN

Acquiring an automated computer based configuration and data management system will greatly enhance the Technical Data Department's ability to perform its mission. At the same time, the development will represent a major capital expenditure for NSWSES and will impact the billet requirements particularly within the Technical Data Department. In order for NSWSES to realize full benefit from the new system, make a smooth transition from the current system without disruption of current services, and minimize the adverse impact on personnel, it will be necessary for the upper levels of management at NSWSES to be aware of the objectives of the new system and to support them. It is therefore recommended that a steering committee be established which shall be responsible for the overall coordination of the acquisition to ensure that it is integrated with all of the NSWSES operations and with other activities external to NSWSES.

Subcommittees should be appointed to provide detailed guidance for specific segments of the system acquisition. A recommended committee arrangement is shown in Fig. 10. The following paragraphs provide general areas of responsibility for each committee. Specific units within NSWSES have been recommended for steering committee membership to ensure overall coordination of the system development. The subcommittee membership should be made up of personnel from NSWSES who have particular technical or other expertise in a given area and an appreciation for the operational objectives of the data management system. Active membership on any of the committees will likely vary at different stages of the acquisition.

5.2.1 The Steering Committee

It is recommended that the Department Head of the Technical Data Department be appointed as the steering committee chairman. He has a working knowledge of the operational objectives of the system, and as a senior manager he has ready access to other senior managers to ensure that the data management system becomes an integral part of the entire NSWSES organization. Each Division Head within the Technical Data Department should be appointed to the committee to identify division requirements and to ensure that an integrated data base is developed which will satisfy these requirements.

The long-range planning group at NSWSES should be represented on the committee to ensure that NSWSES command requirements are considered throughout and to ensure that the acquisition is integrated with the overall NSWSES operation.

During phase 2 and phase 3 of the system acquisition, additional members, such as the engineers and the engineering drafting personnel, should be included as active committee members to ensure that their departments will derive full benefit from the data management system.

The steering committee should use the variables listed below as a basis for determining the overall objectives for the acquisition:

(1) Navy Shipbuilding Program - physical size of the Fleet

(2) System Deployment - number of systems maintained, number of end users

(3) New Responsibility Areas - change in user needs, change in NSWSES cognizant systems, change in responsibility for systems currently managed only in part

(4) NSWSES Personnel Manning Levels - need for increased productivity

The steering committee should give general guidelines on schedule for implementation, integrated data base concept, on-line operational requirements, known cost and time constraints, etc. This will provide the various subcommittees a framework in which to work.

The steering committee should evaluate the possibility of revolutionary changes occurring in the Technical Data Department's responsibility for configuration management, such as, the possible inclusion of the underway replenishment data base, so the impact can be reflected in the data management system acquisition.

The steering committee should consider alternatives developed by the subcommittees and make major alternative tradeoff decisions to satisfy the overall objectives of the system.

5.2.2 The Hardware Subcommittee

The hardware subcommittee should be responsible for selecting system hardware which will most effectively and economically support the system objectives. This will require close coordination with the software subcommittee to ensure system compatibility.

Following are some of the basic considerations which the hardware subcommittee should study:

AVAILABILITY - Hardware should be chosen which is close to the state of the art in order to prolong the life of the overall system.

MAINTAINABILITY AND REPAIRABILITY - A decision must be made as to whether NSWSES will develop its own maintenance and repair. This will involve consideration of both cost and possible system downtime.

OPERATOR TRAINING - The time, disruption, and cost of training personnel must be considered. It is desirable that training time be kept to a minimum.

MODULARITY - The hardware chosen must fulfill current system requirements, be capable of expanding to meet future needs. This is particularly important as the hardware selections made for one phase must also support the additions of later phases.

5.2.3. The Software Subcommittee

The software subcommittee must work in close conjunction with the hardware subcomitteе to develop an operating system which fully exploits the capability of the hardware and fulfills the requirements of the overall system. Some of the considerations for which the software subcommittee should be responsible are given below.

DOCUMENTATION - The documentation from the design phase throughout the system life cycle cannot be overemphasized since it forms the basis for system understanding and operation. This documentation should include computer programs, manuals, and procedures, equipment and facility layout, computer operating procedures, training materials and training programs.

USER TRAINING - The subcommittee should develop a training program for the users of the system.

STANDARDS - The development of standards which must be followed by all users of the system is very important if an integrated data base is to be effective.

INFORMATION FLOW - A study of information flow requirements should be made to ensure that all required information is made available in a timely fashion and that redundant or useless information is not processed.

ACCOUNTABILITY - Procedures should be developed which ensure that only authorized personnel interact with the system and that these personnel be accountable for actions taken.

BACK-UP PROCEDURE - Consideration must be given to methods of operation which can be utilized if the system is inoperative.

5.2.4. The Facilities Subcommittee

This subcommittee should determine the facility requirements for support of the system. The committee must take an overall view of all three phases to ensure that allowance is made for the increased facility requirements as the phases are installed. The possibility of utilizing existing buildings, upgraded to support the system, should be investigated. Close coordination with the hardware committee will be required to ensure that the facilities developed are compatible with the space and support requirements of the hardware.

5.2.5 The Budget/Cost Estimating Subcommittee

This subcommittee must work in close conjunction with all the other subcommittees to ensure that all the requirements are considered and that accurate cost estimates are developed to support preparation of the budget submissions. The subcommittee should be responsible for ensuring that the time and cost constraints prescribed by the steering committee are observed and that necessary tradeoffs between the requirements identified by other subcommittees are presented to the steering committee for final decision.

6. RECOMMENDATIONS FOR FURTHER STUDY

This study has concentrated on a managerial approach to properly organize future investigation and coordination efforts. After the need is justified, NSWSES should turn to studies which will formalize the parameters of the proposed system. These studies may be made by NSWSES personnel, contractors, or Naval Postgraduate School students, depending upon cost and time constraints. The studies could be made by one of the committees discussed in Section 5. These committees should be responsible for collecting data and analyzing it in light of specific user requirements, then making detailed recommendations to the steering committee. This should be a natural product of the acquisition process and need not delay the beginning of the system development cycle.

Areas for additional study are:

(1) Analysis of the expected file sizes projected into the relevant time frame. This should include an analysis of the mass storage requirements for the various functional areas of the system definition.

(2) Analysis of the access times required for each classification of work. For example, routine file maintenance times would probably differ from

the times required for the extraction of engineering drawings.

(3) Simulation and analysis of the proposed system using GPSS or other simulation languages to provide a model for other studies. This work might well be accomplished by Computer Science students at the Postgraduate School in conjunction with the hardware subcommittee.

(4) A tradeoff analysis of a complete on-line system versus on-line query and update/transaction file with a batch file maintenance concept.

(5) Analysis of the actual dollar savings associated with digitized drawings.

(6) Analysis of the actual dollar savings associated with increased productivity of personnel. This analysis can be conducted in phases as the various functional areas are included as users of the system.

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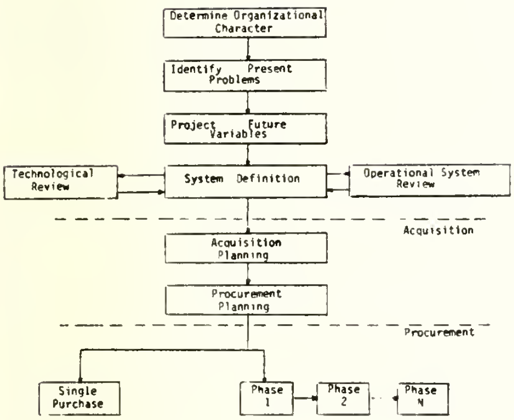

Figure 1 METHODOLOGY BLOCK DIAGRAM

System	Subsystem	Designator	Number (1)
Terrier GMS			34 (3)
	GM Launching System	MK10 Mod0-9	46
	GM Fire Control System	MK71 Mod0-1 MK73 Mod0-1 MK76 Mod0-9	98
	Weapons Direction System	MK1 Mod0 MK3 Mod0-3 MK5 Mod0-2 MK7 Mod0-3 MK11 Mod0-4	33
Tartar GMS			52 (2,3)
	GM Launching System	MK16 Mod4 (Modified) MK11 Mod0-2 MK13 Mod0-4 MK22 Mod0 MK26 Mod0-2 MK32 Mod0-1	52 (2)
	GM Fire Control System	MK74 Mod0-8	54 (2)
	Weapons Direction System	MK4 Mod0-5 MK13 Mod0-1 MK14 Mod0	42 (2)
Talos GMS			5 (3)
	GM Launching System	MK7 Mod0 MK12 Mod0-1	7
	GM Fire Control System	MK77 Mod0-4	5
	Weapons Direction System	MK2 Mod0-1 MK6 Mod0-3	4
Basic Point Defense			50 (3)
	GM Launching System	MK25 Mod0-1	50
	GM Fire Control System	MK115 Mod0	50
5" Gun			2 (3)
	Gun Fire Control System	MK86 Mod3-5	2
AN/SPS-58 Search Radars			11 (3)
Ancillary Equipment		208 Types	Numerous

Notes:

1. Number of ships with this system
2. Includes Tartar used only for surface capability
3. These numbers are those on U.S. ships although some services are provided to allied governments.

Figure 2 SYSTEMS COMPLETELY SUPPORTED

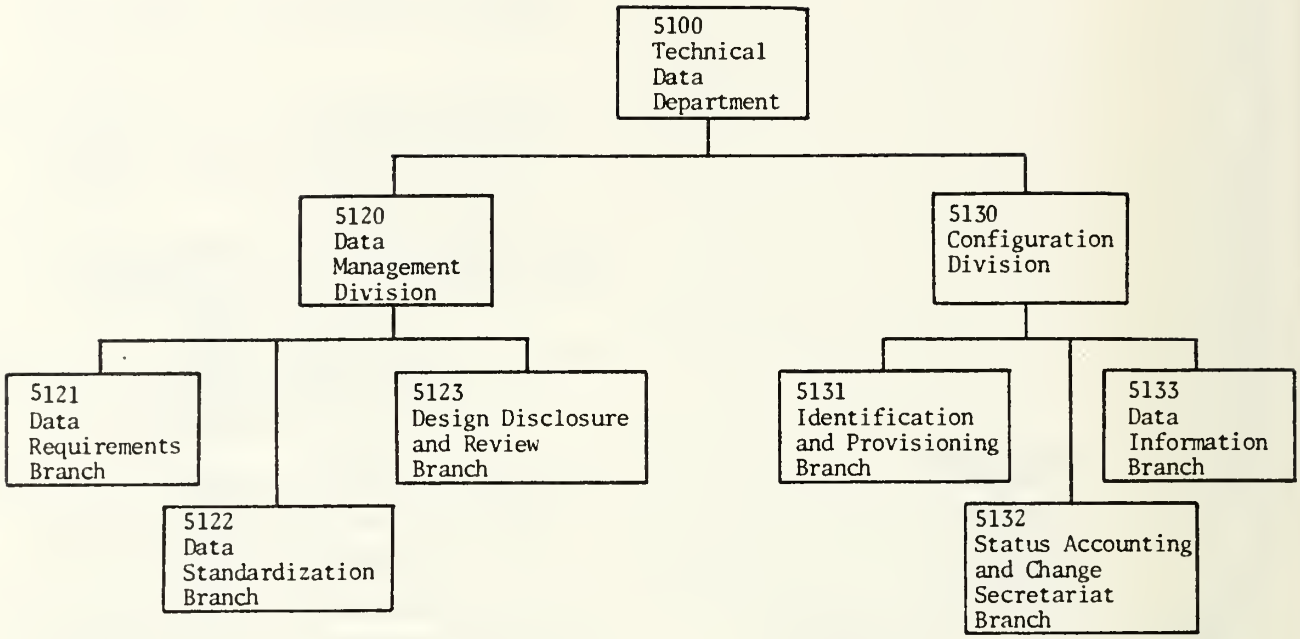

Figure 3 - TECHNICAL DATA DEPARTMENT

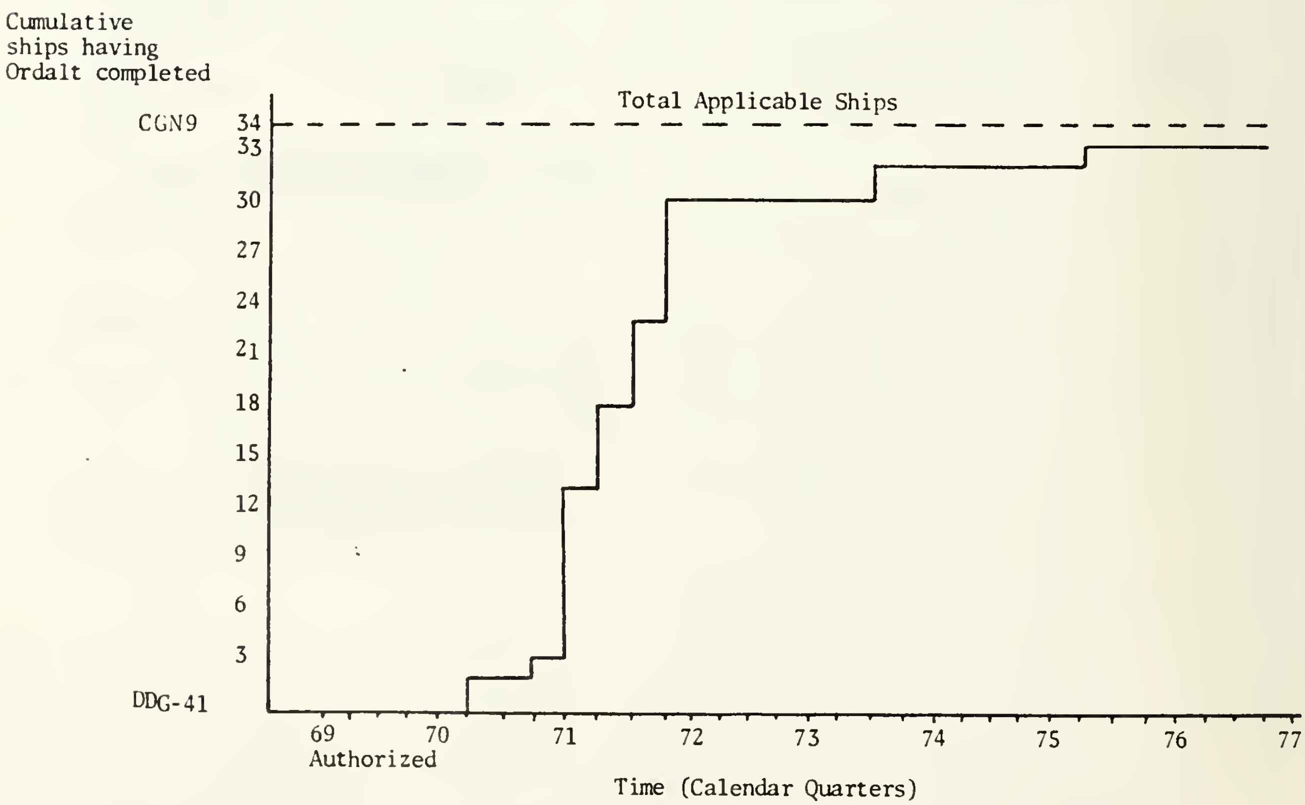

Figure 4 - ORDALT 6865 COMPLETION GRAPH

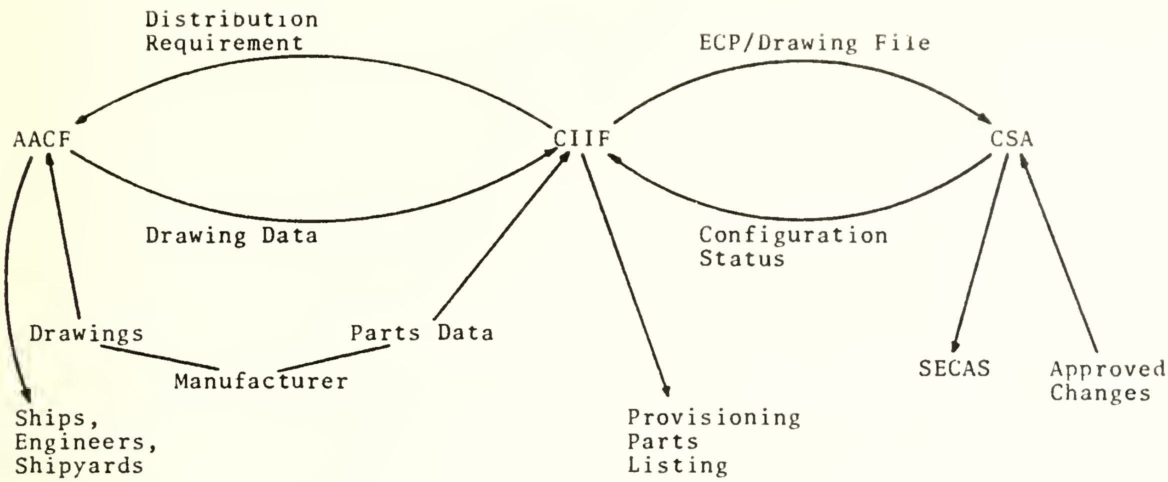

Figure 5 - FILE RELATIONSHIPS

	FY-76	FY-77	FY-78	FY-79	FY-80	FY-81	Total FY76-81
Carriers				1		1	2
Cruisers			1			1	2
Vistol Carrier					1		1
Destroyers		1		2	3	2	8
Frigates	6	8	8	8	8	8	46
Totals	6	9	9	11	12	12	59

Figure 6 - APPROVED NAVY SHIPBUILDING PROGRAM

System	Present	1980-1985
Terrier	34	30-35
Tartar	52	90-95
Talos	7	1-5
NATO Seasparrow	3	55-60
Harpoon	0	180-185
Close-in-Weapons-System	0	190-195
Point Defense	50	55-60
AEGIS	0	1-3
Anti-Ship-Missile-Defense	32	110-115
Totals	181	712-753

Notes:
1. Land based sites and foreign ships are not included.
2. Number of ships with indicated capability is shown. Some of these ships will have multiple capability for a given system.

Figure 7 - CONFIGURATION MANAGED SYSTEMS

	UNICON	TBM	MASSTAPE	Conventional Disk
System Cost	$1.6Million	$3.25Million	$3Million	$200,000
Throughput (Bits/Sec)	$3.4X10^6$	$1.5X10^6$*	10^6	$6.4X10^6$
Capacity (Bits)	$.7X10^{12}$	$3.2X10^{12}$	10^{12}	10^9
Cost/Bit (Cents)	$2.29X10^{-4}$	$1.016X10^{-4}$	$3X10^{-4}$	$2X10^{-2}$
Average Access Time (Seconds)	10	13.3	6	.075

*Function of EDCP selected

Figure 8 - MASS STORAGE COMPARISON

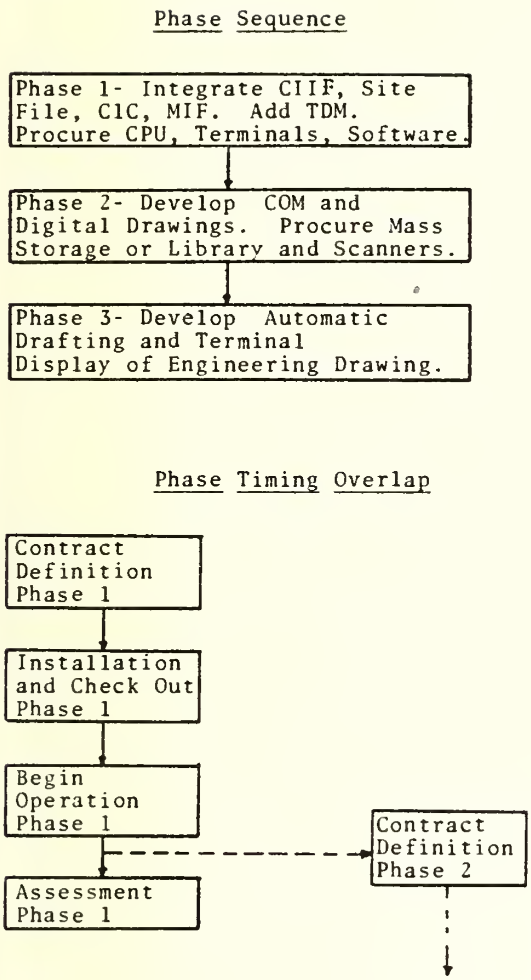

Figure 9 - PHASE TIMING

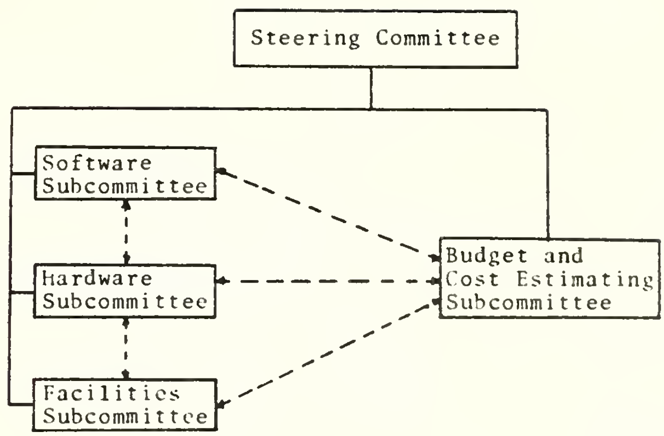

Figure 10 - RECOMMENDED ORGANIZATIONAL STRUCTURE

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